PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

# PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>01 March 2000 (01.03.00) | |
| **International application No.**<br>PCT/DK99/00404 | **Applicant's or agent's file reference**<br>P199800232 wo |
| **International filing date** (day/month/year)<br>15 July 1999 (15.07.99) | **Priority date** (day/month/year)<br>16 July 1998 (16.07.98) |
| **Applicant**<br>BENTZON, Michael, Deleuran | |

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

13 January 2000 (13.01.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

| | |
|---|---|
| **The International Bureau of WIPO**<br>**34, chemin des Colombettes**<br>**1211 Geneva 20, Switzerland** | Authorized officer<br>Nestor Santesso |
| Facsimile No.: (41-22) 740.14.35 | Telephone No.: (41-22) 338.83.38 |

ENT COOPERATION TREATY

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference | **FOR FURTHER ACTION** | see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. |
|---|---|---|
| P199800232 WO | | |
| International application No. | International filing date *(day/month/year)* | (Earliest) Priority Date *(day/month/year)* |
| PCT/DK 99/ 00404 | 15/07/1999 | 16/07/1998 |
| Applicant | | |
| NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S et al. | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

# INTERNATIONAL SEARCH REPORT

International Application No
PC[redacted]UK 99/00404

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | DE 24 31 505 B (SIEMENS AG)<br>17 April 1975 (1975-04-17)<br>cited in the application<br>column 3, line 6 - line 67<br>column 5, line 36 -column 6, line 3<br>column 10, line 28 - line 44; claims<br>1,3,5,6 | 1-3,5-8,<br>10,13 |
| P,Y | US 5 894 223 A (MEDELIUS PEDRO J ET AL)<br>13 April 1999 (1999-04-13)<br>abstract<br>column 4, line 26 -column 5, line 34 | 1-3,5-8,<br>10,13 |
| A | DE 26 06 504 A (SIEMENS AG)<br>25 August 1977 (1977-08-25)<br>claims 1-3 | 1,5 |

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 25 October 1999 | 02/11/1999 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Haasbroek, J |

2

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 99/00404

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | DE 197 17 283 C (KARLSRUHE FORSCHZENT)<br>23 April 1998 (1998-04-23)<br>abstract; figure 1 | 1,5 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Info n on patent family members

Int[redacted]ional Application No
PCT/DK 99/00404

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| DE 2431505 B | 17-04-1975 | CA 1031036 A | 09-05-1978 |
| | | CH 579778 A | 15-09-1976 |
| | | FR 2277348 A | 30-01-1976 |
| | | GB 1499164 A | 25-01-1978 |
| | | IT 1039442 B | 10-12-1979 |
| | | JP 51025995 A | 03-03-1976 |
| | | NL 7506562 A | 05-01-1976 |
| | | SE 400386 B | 20-03-1978 |
| | | SE 7507405 A | 02-01-1976 |
| | | US 3976934 A | 24-08-1976 |
| US 5894223 A | 13-04-1999 | NONE | |
| DE 2606504 A | 25-08-1977 | CH 594892 A | 31-01-1978 |
| | | FR 2357908 A | 03-02-1978 |
| | | GB 1508565 A | 26-04-1978 |
| | | JP 52100283 A | 23-08-1977 |
| | | US 4132949 A | 02-01-1979 |
| DE 19717283 C | 23-04-1998 | EP 0874246 A | 28-10-1998 |
| | | JP 2911871 B | 23-06-1999 |
| | | JP 10300723 A | 13-11-1998 |

PATENT COOPERATION TREA

From the INTERNATIONAL BUREAU

# PCT

## NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

HOFMAN-BANG A/S
Hans Bekkevolds Allé 7
DK-2900 Hellerup
DANEMARK

| | |
|---|---|
| Date of mailing (day/month/year)<br>26 August 1999 (26.08.99) | |
| Applicant's or agent's file reference<br>P199800232 wo | **IMPORTANT NOTIFICATION** |
| International application No.<br>PCT/DK99/00404 | International filing date (day/month/year)<br>15 July 1999 (15.07.99) |
| International publication date (day/month/year)<br>Not yet published | Priority date (day/month/year)<br>16 July 1998 (16.07.98) |
| Applicant<br>NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S et al | |

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

| Priority date | Priority application No. | Country or regional Office or PCT receiving Office | Date of receipt of priority document |
|---|---|---|---|
| 16 July 1998 (16.07.98) | PA 1998 00944 | DK | 05 Augu 1999 (05.08.99) |
| 11 Sept 1998 (11.09.98) | PA 1998 01148 | DK | NR |

**The International Bureau of WIPO**
**34, chemin des Colombettes**
**1211 Geneva 20, Switzerland**

Facsimile No. (41-22) 740.14.35

Authorized officer

Beatriz Morariu

Telephone No. (41-22) 338.83.38



EL728210476US

U013198-2 WO 00/04397
PCT/DK99/00404

# PATENT COOPERATION TREATY

VDL

PCT

From the INTERNATIONAL BUREAU

To:
HOFMAN-BANG A/S
Hans Bekkevolds Allé 7
DK-2900 Hellerup
DANEMARK

Opdat KOPI TAGET

## NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>27 January 2000 (27.01.00) | |
| **Applicant's or agent's file reference**<br>P199800232 wo MHC | **IMPORTANT NOTICE** |

| **International application No.** | **International filing date** (day/month/year) | **Priority date** (day/month/year) |
|---|---|---|
| PCT/DK99/00404 | 15 July 1999 (15.07.99) | 16 July 1998 (16.07.98) |

**Applicant**
NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,CN,EP,IL,JP,KP,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CU,CZ,DE,DK,EA,EE,ES,FI,GB,GD,GE,GH,GM,HR,
   HU,ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MD,MG,MK,MN,MW,MX,NO,NZ,OA,PL,PT,RO,RU,
   SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,UA,UG,UZ,VN,YU,ZA,ZW
   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   27 January 2000 (27.01.00) under No. WO 00/04397

### REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

### REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

| | |
|---|---|
| **The International Bureau of WIPO**<br>**34, chemin des Colombettes**<br>**1211 Geneva 20, Switzerland** | Authorized officer<br>J. Zahra |
| Facsimile No. (41-22) 740.14.35 | Telephone No. (41-22) 338.83.38 |

# PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

## PCT

**INFORMATION CONCERNING ELECTED OFFICES NOTIFIED OF THEIR ELECTION**

(PCT Rule 61.3)

To:

HOFMAN-BANG A/S
Hans Bekkevolds Allé 7
DK-2900 Hellerup
DANEMARK

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>01 March 2000 (01.03.00) | |
| **Applicant's or agent's file reference**<br>P199800232 wo HHB | **IMPORTANT INFORMATION** |

| **International application No.** | **International filing date** (day/month/year) | **Priority date** (day/month/year) |
|---|---|---|
| PCT/DK99/00404 | 15 July 1999 (15.07.99) | 16 July 1998 (16.07.98) |

**Applicant**
NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S et al

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

   AP :GH,GM,KE,LS,MW,SD,SL,SZ,UG,ZW
   EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
   National :AU,BG,BR,CA,CN,CZ,DE,IL,JP,KP,KR,MN,NO,NZ,PL,RO,RU,SE,SK,US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

   EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
   OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
   National :AE,AL,AM,AT,AZ,BA,BB,BY,CH,CU,DK,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU, ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MD,MG,MK,MW,MX,PT,SD,SG,SI,SL,TJ, TM,TR,TT,UA,UG,UZ,VN,YU,ZA,ZW

3. The applicant is reminded that he must enter the "national phase" **before the expiration of 30 months from the priority date** before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing , if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

   Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

   The entry into the European regional phase is postponed **until 31 months from the priority date** for all States designated for the purposes of obtaining a European patent.

**The International Bureau of WIPO**
**34, chemin des Colombettes**
**1211 Geneva 20, Switzerland**
Facsimile No. (41-22) 740.14.35

Authorized officer:
Nestor Santesso
Telephone No. (41-22) 338.83.38

U013198-2

# PCT

## REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only HEH/MLR

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* P199800232 WO

**Box No. I TITLE OF INVENTION** A method for the determination of the critical current for a conductor including superconducting material, and an apparatus for performing the method

**Box No. II APPLICANT**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S
Priorparken 878
DK-2605 Brøndby
Denmark

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: DK Denmark

State *(that is, country)* of residence: DK Denmark

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

**Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

BENTZON, Michael Deleuran
Grønnegården 677B
DK-2670 Greve
Denmark

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence: DK Denmark

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

**Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Hofman-Bang A/S
Hans Bekkevolds Allé 7
DK-2900 Hellerup
Denmark

Telephone No. +45 39 48 80 00

Facsimile No. +45 39 48 80 80

Teleprinter No. 19 085 HBB DK

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.



EL728210476US

**Box No.V DESIGNATION OF STATES**

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

**Regional Patent**

- ☒ **AP** **ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ **EA** **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ **EP** **European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ **OA** **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

**National Patent** *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☒ **AE** United Arab Emirates
- ☒ **AL** Albania .....
- ☒ **AM** Armenia .....
- ☒ **AT** Austria .....and Utility Model
- ☒ **AU** Australia .....
- ☒ **AZ** Azerbaijan
- ☒ **BA** Bosnia and Herzegovina .....
- ☒ **BB** Barbados
- ☒ **BG** Bulgaria .....
- ☒ **BR** Brazil .....
- ☒ **BY** Belarus .....
- ☒ **CA** Canada
- ☒ **CH and LI** Switzerland and Liechtenstein
- ☒ **CN** China .....
- ☒ **CU** Cuba .....
- ☒ **CZ** Czech Republic ..and Utility Model
- ☒ **DE** Germany .....and Utility Model
- ☒ **DK** Denmark .....and Utility Model
- ☒ **EE** Estonia .....and Utility Model
- ☒ **ES** Spain .....
- ☒ **FI** Finland .....and Utility Model
- ☒ **GB** United Kingdom
- ☒ **GD** Grenada
- ☒ **GE** Georgia .....
- ☒ **GH** Ghana .....
- ☒ **GM** Gambia
- ☒ **HR** Croatia .....
- ☒ **HU** Hungary .....
- ☒ **ID** Indonesia
- ☒ **IL** Israel .....
- ☒ **IN** India .....
- ☒ **IS** Iceland
- ☒ **JP** Japan .....
- ☒ **KE** Kenya .....
- ☒ **KG** Kyrgyzstan .....
- ☒ **KP** Democratic People's Republic of Korea .....
- ☒ **KR** Republic of Korea .....
- ☒ **KZ** Kazakhstan .....
- ☒ **LC** Saint Lucia
- ☒ **LK** Sri Lanka
- ☒ **LR** Liberia
- ☒ **LS** Lesotho .....
- ☒ **LT** Lithuania
- ☒ **LU** Luxembourg
- ☒ **LV** Latvia
- ☒ **MD** Republic of Moldova .....
- ☒ **MG** Madagascar .....
- ☒ **MK** The former Yugoslav Republic of Macedonia .....
- ☒ **MN** Mongolia
- ☒ **MW** Malawi .....
- ☒ **MX** Mexico .....
- ☒ **NO** Norway
- ☒ **NZ** New Zealand .....
- ☒ **PL** Poland .....
- ☒ **PT** Portugal .....
- ☒ **RO** Romania
- ☒ **RU** Russian Federation .....
- ☒ **SD** Sudan
- ☒ **SE** Sweden
- ☒ **SG** Singapore
- ☒ **SI** Slovenia .....
- ☒ **SK** Slovakia .....and Utility Model
- ☒ **SL** Sierra Leone .....
- ☒ **TJ** Tajikistan .....
- ☒ **TM** Turkmenistan .....
- ☒ **TR** Turkey .....
- ☒ **TT** Trinidad and Tobago .....
- ☒ **UA** Ukraine .....
- ☒ **UG** Uganda .....
- ☒ **US** United States of America .....
- ☒ **UZ** Uzbekistan .....
- ☒ **VN** Viet Nam .....
- ☒ **YU** Yugoslavia .....
- ☒ **ZA** South Africa .....
- ☒ **ZW** Zimbabwe .....

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

- ☐ .....
- ☐ .....

**Precautionary Designation Statement:** In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

**Box No. VI PRIORITY CLAIM** ☐ Further priority claims are indicated in the Supplemental Box.

| Filing date of earlier application (day/month/year) | Number of earlier application | Where earlier application is: national application: country | regional application:* regional Office | international application: receiving Office |
|---|---|---|---|---|
| item (1) 16 July 1998 | PA 1998 00944 | Denmark | | |
| item (2) 11 September 1998 | PA 1998 01148 | Denmark | | |
| item (3) | | | | |

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): _____

** Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

**Box No. VII INTERNATIONAL SEARCHING AUTHORITY**

**Choice of International Searching Authority (ISA)** *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA / EP

**Request to use results of earlier search; reference to that search** *(if an earlier search has been carried out by or requested from the International Searching Authority):*

| Date (day/month/year) | Number | Country (or regional Office) |
|---|---|---|
| 16 July 1998 | DK 98/00095 | Denmark |

**Box No. VIII CHECK LIST; LANGUAGE OF FILING**

This international application contains the following **number of sheets**:

| | | |
|---|---|---|
| request | : | 3 |
| description (excluding sequence listing part) | : | 13 |
| claims | : | 4 |
| abstract | : | 1 |
| drawings | : | 4 |
| sequence listing part of description | : | - |
| **Total number of sheets** | : | 25 |

This international application is **accompanied by** the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☒ priority document(s) identified in Box No. VI as item(s): (1)
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☒ other *(specify)*: DK 98/00095

**Figure of the drawings** which should accompany the abstract: 1

**Language of filing** of the international application: English

**Box No. IX SIGNATURE OF APPLICANT OR AGENT**

*Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).*

Nordic Superconductor Technologies A/S

Per Vase
Vice President

Per Vase, Vice President

Michael Deleuran Bentzon

**For receiving Office use only**

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid.

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Date of receipt of the record copy by the International Bureau:

# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference | FOR FURTHER ACTION | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
|---|---|---|
| P199800232 wo | | |
| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
| PCT/DK99/00404 | 15/07/1999 | 16/07/1998 |
| International Patent Classification (IPC) or national classification and IPC<br>G01R33/12 | | |
| Applicant<br>NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S et al. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 13/01/2000 | 30.03.2000 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Wille, H-J<br>Telephone No. +49 89 2399 6725 |

Form PCT/IPEA/409 (cover sheet) (January 1994)

EL728210470US

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK99/00404

## I. Basis of th r port

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

**Description, pages:**

1-13 as originally filed

**Claims, No.:**

1-13 as originally filed

**Drawings, sheets:**

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-13 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 1-13 |
| | No: | Claims | |
| Industrial applicability (IA) | Yes: | Claims | 1-13 |
| | No: | Claims | |

2. Citations and explanations

**see separate sheet**

## VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

**see separate sheet**

## Re Item V

**Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

The invention relates to a method for determining the critical current for a superconducting conductor and to an apparatus for performing the method.

DE-A-24 31 505 = D1 is regarded as closest prior art against which claim 1 has been delimited. In the D1 method the conductor is conveyed through a varying external magnetic field while being in a superconducting state. As consequence, a shielding field is generated in the conductor which generates induced shielding currents reaching the value of the critical current. An external touchless measurement means detects the overall field from which the induced currents are derived.

The invention distinguishes therefrom by using the part of the resulting magnetic field which is out of phase with the external field as a basis for the determination of the critical current. This measure allows a better and more reliable determination.

DE-A-26 06 504 discusses the method of D1 using two axially spaced, external magnetic fields the direction of which being offset against each other. DE-A-19 717 283 discloses a respective method having two measurement means being differently arranged.

Conclusively, there is no incitation in the prior art to use the above mentioned out of phase portion so that the subject-matter of claim 1 and, respectively, that of claim 5 is based on an inventive step. The dependent claims 2 to 4 and 6 to 13 include all features of the independent claims they are referred to and involve likewise an inventive step.

## Re Item VI

**Certain documents cited**

Certain published documents (Rule 70.10)

**INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/DK99/00404

| Application No<br>Patent No | Publication date<br>*(day/month/year)* | Filing date<br>*(day/month/year)* | Priority date *(valid claim)*<br>*(day/month/year)* |
|---|---|---|---|
| US-A-5 894 223 | 13.4.1999 | 24.9.1997 | - |

**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01R 33/12 — A1

(11) International Publication Number: **WO 00/04397**

(43) International Publication Date: 27 January 2000 (27.01.00)

(21) International Application Number: PCT/DK99/00404

(22) International Filing Date: 15 July 1999 (15.07.99)

(30) Priority Data:
PA 1998 00944 16 July 1998 (16.07.98) DK
PA 1998 01148 11 September 1998 (11.09.98) DK

(71) Applicant *(for all designated States except US)*: NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S [DK/DK]; Priorparken 878, DK–2605 Brøndby (DK).

(72) Inventor; and

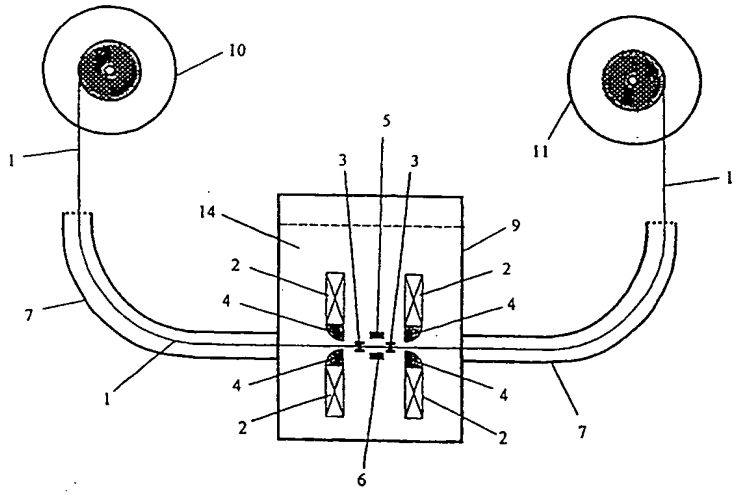
(75) Inventor/Applicant *(for US only)*: BENTZON, Michael, Deleuran [–/DK]; Grønnegården 677B, DK–2670 Greve (DK).

(74) Agent: HOFMAN–BANG A/S; Hans Bekkevolds Allé 7, DK–2900 Hellerup (DK).

(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published**
*With international search report.*

(54) Title: A METHOD FOR THE DETERMINATION OF THE CRITICAL CURRENT FOR A CONDUCTOR INCLUDING SUPERCONDUCTING MATERIAL, AND AN APPARATUS FOR PERFORMING THE METHOD




(57) Abstract

The invention relates to a method for the determination of the critical current for a conductor including superconducting material. The conductor is brought into a superconducting state, and a varying external magnetic field is generated through which said conductor is conveyed. A first measurement means is used to carry out a first contact–free measurement of the resulting magnetic field that occurs as a consequence of the influence of said external magnetic field on the conductor. The part of the resulting magnetic field out of phase with the external magnetic field is determined, and the critical current of the conductor is determined on the basis thereof. The invention further relates to an apparatus for performing the method.

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# INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/DK 99/00404

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | DE 24 31 505 B (SIEMENS AG)<br>17 April 1975 (1975-04-17)<br>cited in the application<br>column 3, line 6 - line 67<br>column 5, line 36 -column 6, line 3<br>column 10, line 28 - line 44; claims<br>1,3,5,6 | 1-3,5-8,<br>10,13 |
| P,Y | US 5 894 223 A (MEDELIUS PEDRO J ET AL)<br>13 April 1999 (1999-04-13)<br>abstract<br>column 4, line 26 -column 5, line 34 | 1-3,5-8,<br>10,13 |
| A | DE 26 06 504 A (SIEMENS AG)<br>25 August 1977 (1977-08-25)<br>claims 1-3 | 1,5 |

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 25 October 1999 | 02/11/1999 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Haasbroek, J |

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# INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/DK 99/00404

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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|---|---|---|
| A | DE 197 17 283 C (KARLSRUHE FORSCHZENT)<br>23 April 1998 (1998-04-23)<br>abstract; figure 1 | 1,5 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

.. ormation on patent family members

Internr ·al Application No
PCT/UK 99/00404

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| DE 2431505 B | 17-04-1975 | CA 1031036 A | 09-05-1978 |
| | | CH 579778 A | 15-09-1976 |
| | | FR 2277348 A | 30-01-1976 |
| | | GB 1499164 A | 25-01-1978 |
| | | IT 1039442 B | 10-12-1979 |
| | | JP 51025995 A | 03-03-1976 |
| | | NL 7506562 A | 05-01-1976 |
| | | SE 400386 B | 20-03-1978 |
| | | SE 7507405 A | 02-01-1976 |
| | | US 3976934 A | 24-08-1976 |
| US 5894223 A | 13-04-1999 | NONE | |
| DE 2606504 A | 25-08-1977 | CH 594892 A | 31-01-1978 |
| | | FR 2357908 A | 03-02-1978 |
| | | GB 1508565 A | 26-04-1978 |
| | | JP 52100283 A | 23-08-1977 |
| | | US 4132949 A | 02-01-1979 |
| DE 19717283 C | 23-04-1998 | EP 0874246 A | 28-10-1998 |
| | | JP 2911871 B | 23-06-1999 |
| | | JP 10300723 A | 13-11-1998 |

**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01R 33/12 — A1

(11) International Publication Number: **WO 00/04397**

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(30) Priority Data:
PA 1998 00944 16 July 1998 (16.07.98) DK
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(71) Applicant *(for all designated States except US)*: NORDIC SUPERCONDUCTOR TECHNOLOGIES A/S [DK/DK]; Priorparken 878, DK–2605 Brøndby (DK).

(72) Inventor; and

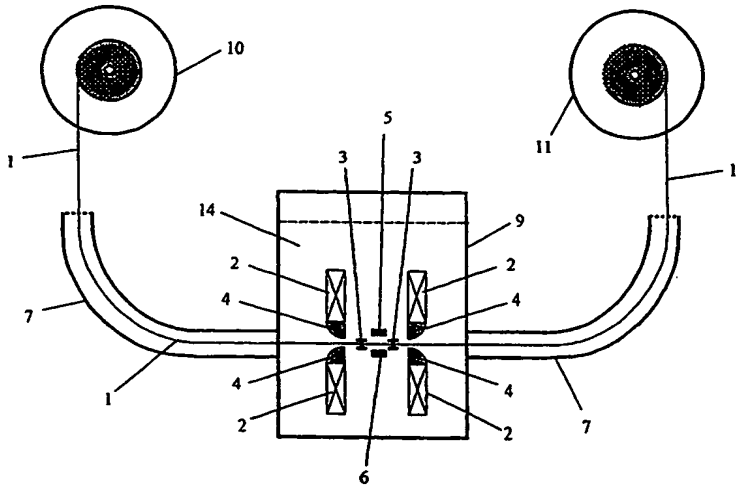
(75) Inventor/Applicant *(for US only)*: BENTZON, Michael, Deleuran [–/DK]; Grønnegården 677B, DK–2670 Greve (DK).

(74) Agent: HOFMAN–BANG A/S; Hans Bekkevolds Allé 7, DK–2900 Hellerup (DK).

(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published**
*With international search report.*

(54) Title: A METHOD FOR THE DETERMINATION OF THE CRITICAL CURRENT FOR A CONDUCTOR INCLUDING SUPERCONDUCTING MATERIAL, AND AN APPARATUS FOR PERFORMING THE METHOD




(57) Abstract

The invention relates to a method for the determination of the critical current for a conductor including superconducting material. The conductor is brought into a superconducting state, and a varying external magnetic field is generated through which said conductor is conveyed. A first measurement means is used to carry out a first contact–free measurement of the resulting magnetic field that occurs as a consequence of the influence of said external magnetic field on the conductor. The part of the resulting magnetic field out of phase with the external magnetic field is determined, and the critical current of the conductor is determined on the basis thereof. The invention further relates to an apparatus for performing the method.

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# A method for the determination of the critical current for a conductor including superconducting material, and an apparatus for performing the method

The invention relates to the determination of the critical current for a conductor including superconducting material, and to an apparatus for performing the method.

Conductors comprising superconducting material have different uses, e.g. in connection with magnets, transformers, and as conductors for electrical power distribution. Superconducting material is advantageously used in conductors as the superconducting material can be brought into a superconducting state enabling electrical energy to be transmitted with little energy loss. Reduced electrical power loss is also advantageous as it enables construction of e.g. transformers, magnets, and conductors with smaller dimensions compared to the use of conventional conductors.

Conductors comprising superconducting material can be constructed as a single core conductor, but is often constructed as a number of filaments arranged to form a multi-core conductor.

When a superconductor is brought into the superconduction state, e.g. by cooling, electrical power can be transmitted with little loss, as long as the current is lower than the so-called critical current. The critical current, i.e. that current which the superconductor material is able to support without going into a normally conductive state, is a characteristic value of the given superconductor. It is of great importance to determine the critical current for a conductor comprising

superconducting material, as the value of the critical current is needed when dimensioning e.g. a transformer including superconductors.

As the value of the critical current may vary along the conductor, it is of interest to determine the critical current along the superconductor in order to characterize the superconductor. It is of interest to perform the characterization of the conductor as a contact-less measurement as it enables a continuous determination of the critical current for a conductor over the entire length of the conductor. In addition, the contact-less measurement has the advantage of saving the conductor and the measurement means from wear due to mechanical contact.

A method and an apparatus for testing a conductor which consists at least partially of superconductive material is disclosed in US patent 3,976,934. The patent teaches that the testing of a conductor with superconductive material in the superconducting state can be performed by moving the conductor through an external magnetic field which induces shielding currents in the superconductor material and by measuring the magnetic field generated by these shielding currents. The critical current is determined using the measured shielding field.

The object of the invention is to provide a method for the determination of the critical current for a conductor including superconducting material, which method gives a better and more reliable determination than methods according to the prior art.

This object is achieved by performing the method as stated in the characterizing portion of claim 1.

According to the invention, the determination of the critical current for a conductor including superconducting material is performed using a method, wherein said conductor is brought into a superconducting state, and wherein a varying external magnetic field is generated, through which said conductor is conveyed, and wherein a first measurement means is used to carry out a first contact-free measurement of the resulting magnetic field that occurs as a consequence of the influence of the conductor by said external magnetic field. The part of the resulting magnetic field out of phase with the external magnetic field is determined, and the critical current of the conductor is determined on the basis thereof.

The method according to the invention is advantageous as it uses a so-called coupling of the filaments in a conductor having a multi-filament structure to obtain a larger signal to noise ratio for the measured signal due to the fact that the measurement is performed on all the filaments in the conductor. The resulting magnetic field is larger when the filaments are coupled, as each filament hereby contributes constructively to the generation of the resulting magnetic field.

The method according to the invention is advantageous over prior art methods in which the resulting magnetic field, which reflects the value of the critical value, is relatively small due to field suppression. Due to field suppression, that the superconducting characteristics of a superconductor are reduced when exposed to a external magnetic field. Field suppression results in a relatively small magnetic field which reflect the critical current which provides a relatively small signal to noise ratio in the measured signal.

Using a method according to the prior art, it is difficult to obtain an optimum magnetic field in practice as both a too small and a too large external magnetic field result in a magnetic field which is lower than the optimum magnetic field. An optimum external field, when using a method according to the prior art, is a field that is large enough to induce shielding currents in the entire cross-section of the superconductor material to reach the critical current density. As the value of an optimum external value typically varies along the conductor, the measured magnetic field will therefore reflect this unwanted effect. These difficulties are avoided when using a method according to the invention as that part of the resulting magnetic field which is out of phase with the external magnetic field is used to determine the critical current.

In a preferred embodiment, a second measurement is carried out on the resulting magnetic field from another side in relation to the conductor by using a second measurement means. This second measurement is performed in addition to said first measurement of the resulting magnetic field from a first side in relation to the conductor. On the basis of these measurements, a more reliable result can be obtained. It also permits a supervision of the measurement. For example, it is possible to determine the distance between the conductor and the measurement means, and hereby to supervise the conveyance of the conductor, and it is possible to observe differences between the measurements of the different measurement means, which can e.g. be caused by ice on the measurement means.

In a preferred embodiment, compensation is made for measurement variations that occur as a consequence of

variations in distance between conductor and measurement means. This compensation is made on the basis of said first measurement, or any value derived therefrom, and on the basis of said second measurement, or any value derived therefrom.

It is particularly advantageous to perform said compensation by means of the formula $U=((A+B)-k(A-B)^2)/2$, wherein a corrected field value U is determined on the basis of the value A that is the field value from said first measurement or a value derived therefrom, and on the basis of the value B that is the field value of said second measurement or a value derived therefrom.

The invention also relates to an apparatus for the determination of the critical current for a conductor including a superconducting material adapted to perform the method according to the invention.

The apparatus comprises a conveyor arranged to convey the conductor through the apparatus, a cryostat arranged to cool the conductor to make it assume a superconducting state, a field generation device arranged to generate a varying magnetic field through which the conductor is conveyed, and a first measurement means arranged to carry out a measurement of the resulting magnetic field that occurs as a consequence of the influence of said magnetic field on said conductor. The apparatus further comprises means arranged to determine, on the basis of the measured magnetic field, that part which is out of phase with the resulting magnetic field, and on the basis of this to determine the critical current of the conductor.

In a preferred embodiment of the invention the field generating device comprises Helmholtz coils.

In a preferred embodiment, said first measurement means in the apparatus is arranged to carry out a measurement of the resulting magnetic field from a first side in relation to the conductor, and the apparatus further comprises a second measurement means arranged to carry out a measurement of the resulting magnetic field from another side in relation to the conductor. This is advantageous as the apparatus can be used to perform a more reliable measurement, and to supervise the measurement. Hereby it is possible to determine the distance between the conductor and the measurement means, and to supervise the conveyance of the conductor. By observing the measurements from the different measurement means, it is also possible to determine the differences, which e.g. can be caused by ice on the measurement means.

The apparatus advantageously comprises compensating means arranged to compensate, on the basis of measurements from said first and said second measurement means or values derived therefrom, for measurement variations due to the distance between conductor and measurement means.

Said compensating means is advantageously arranged to carry out said compensation by using the formula $U=((A+B)-k(A-B)^2)/2$, wherein a corrected field value U is determined on the basis of said measured field value A from said first measurement means or any value derived therefrom, and on the basis of the measured field value B from said second measurement means or any value derived therefrom.

In a preferred embodiment, said cryostat comprises a mechanical control device for controlling the conveyance of the conductor through the cryostat, and said cryostat

is arranged to contain a coolant for cooling the conductor.

In a preferred embodiment, the apparatus comprises two separate guides between which the conductor is freely suspended, and said field generating device and measurement device are arranged between the two guides. This is advantageous as the cryostat does not include any movable parts. It is further advantageous as the cryostat does not include components which could influence the measurements.

Said control device advantageously comprises two slide guides, which is advantageous due to the simple and hereby sturdy construction.

In a preferred embodiment of the apparatus said guides are made of high density polyethylene. This is advantageous as this material can withstand the influence from the environment.

The invention will be explained more fully by the following description with reference to the drawing, in which

fig. 1 is a side view of an apparatus according to the present invention,

fig. 2 shows a section of the apparatus according to the invention from a second side,

fig. 3 illustrates the coupling of filaments in a conductor including superconducting material, and

fig. 4 illustrates the relationship between the shielding field and the external magnetic field, and the

relationship between the remanent field and the external magnetic field.

Fig. 1 shows a preferred embodiment of an apparatus according to the invention. The cryostat containing the cooling medium 14 consists of a central vessel 9 and two tubes 7. A conductor 1 including superconducting material is conveyed from a coil 10 into the cryostat 7,9 through a field generating device 2, out of the cryostat and recoiled 11. The apparatus also comprises a mechanical control device which is designed to assure that the conductor movement in vertical and horizontal directions is restricted and that the conductor is not exposed to bending radius smaller than a given value, e.g. 200 mm. The field generating device 2, which is also called the magnet 2 hereinafter, may be constructed as a pair of Helmholtz coils. In the magnet 2 the field, B, is normal to the conductor surface and the field strength is advantageously high enough to obtain twice the field of full penetration for the actual superconductor. A first measurement means 5 and a second measurement means 6 are placed above and below the tape respectively. The measurement means 5,6, which are also called magnetic sensors 5,6 hereinafter, may e.g. be Hall probes, inductance coils, or superconducting circuits (squids).

The mechanical control device comprises two slide guides 3,4, which is advantageous due to the simple and hereby sturdy construction. The conductor is freely suspended between the two slide guides which are separated. The field generating device and the measurement device are arranged between the two guides. This is advantageous as the cryostat does not include any movable parts. It is further advantageous as the cryostat does not include components which could influence the performed measurements. The guides are made of high density

polyethylene, but can be made of other material if desired.

When the conductor 1 is conveyed through the apparapus, by using a conveyor (not shown), the conductor is conveyed through the cooling medium 14 and is hereby brought into a superconducting state. The magnet 2 is adapted to generate a varying external magnetic field through which said conductor is conveyed. Hereby a magnetic field is generated. A first contact-free measurement of the resulting magnetic field that occurs as a consequence of the influence of said external magnetic field on the conductor is carried out using the first measurement means 5. The resulting magnetic field is also measured from another side in relation to the conductor using the second measurement means 6. It is advantageous to perform both the first and the second measurement, as they result in a more reliable measurement and make it possible to supervise the measurement, e.g. to determine the distance between the conductor and the measurement means, and hereby to supervise the conveyance of the conductor. It is also advantageous as it permits observation of differences between the measurements of the different measurement means 5,6, which can e.g. be caused by ice on the measurement means 5,6, or be caused by defects.

The resulting magnetic field is a sum of the external field and the field induced by the superconductor, i.e. the so-called self-field. The self-field contains information about the superconducting properties of the tape. These properties are the critical current, the critical current distribution and density, distribution of induced superconducting and non-superconducting currents, coupling of filaments, filament geometry, induced AC losses, field suppression, etc. All of these

properties will influence the amplitude and time dependence of the self-field. It is noted that the frequency of the varying external magnetic field is given a certain high value in order to ensure coupling of all the filaments in the conductor 1.

It is determined on the basis of the measurement which part of the resulting magnetic field is out of phase with the external magnetic field. The critical current is determined on the basis thereof. It is noted that the part of the measured magnetic field which is in phase and out of phase with the external field will be close to the shielding field and the remanent field respectively and are taken as the most important parameters describing the superconducting properties of the conductor 1.

On basis of the first measurement, or any value derived therefrom, and on the basis of said second measurement, or any value derived therefrom, a compensation is made for measurement variations that occur as a consequence of variations in distance between conductor 1 and measurement means 5,6. The compensation is e.g. performed by means of the formula $U=((A+B)-k(A-B)^2)/2$, wherein a corrected field value U is determined on the basis of the value A that is the field value from said first measurement or a value derived therefrom, and on the basis of the value B that is the field value of said second measurement or a value derived therefrom. It is noted, that k is a constant having a given value, e.g. 0.42.

The method according to the invention is advantageous as the coupling of the filaments in a conductor having a multi-filament structure provides a larger signal to noise ratio for the measured signal due to the fact that

the measurement is performed on all the filaments in the conductor simultaneously. The resulting magnetic field is larger when the filaments are coupled, which will be described in the following.

Fig. 2 shows a section of the apparatus of fig. 1 from a second side. The conveyer means 3 are designed to keep the tape steady in horizontal as well as vertical directions.

The conductor 1, which comprises superconducting material, is formed as a tape and includes a number of filaments 8 arranged to form a multi-core conductor. The conductor 1 is also called the tape 1 hereinafter, even though the conductor can also be formed in other ways.

Each filament 8 comprises superconducting material and is typically enclosed by another material e.g. silver, in order to give a flexible structure. Different types of superconducting materials are used, and can e.g. comprise Bismuth (Bi), Strontium (Sr), Calcium (Ca) and Copper (Cu) in a given ratio.

The filaments 8 in the tape 1 may be coupled due to the time derivative of the external magnetic field. The effect of coupling is that the filaments appear as one superconductor, and this is illustrated by the field lines 20 representing the lines from a single superconductor.

Fig. 3 illustrates the importance of filament coupling. The figure shows the field above two tapes where the filaments are not coupled (left) and where the filaments are coupled (right). Coupling of filaments increases with the time derivative of the field and with the conductivity of the matrix material. Coupling of the

filaments makes the superconducting currents couple together into one loop carrying the critical current. The magnetic field obtained by such a loop is much stronger than the field obtained by several loops. This is illustrated in the figure by only two filaments. The effect increases with the number of filaments. When the filaments couple, the magnetic field is much bigger and more easy to measure and the relation between the measured field and the critical current is simple to calculate by using Biot-Savart´s law.

Fig. 4 illustrates the relationship between the shielding field and the external magnetic field, and the relationship between the remanent field and the external magnetic field. The critical current carried by the superconductor depends on the amplitude of the external field. This is due to the field suppression. The remanent field will increase with the external field until saturation occurs around twice the field of full penetration. Then the remanent field is saturated. The shielding field will start decreasing at higher fields due to the field suppression. The remanent field is advantageously measured when the external field is zero, while the shielding field is at its maximum value. The remanent field will be a measure of the critical current at zero external field (self field).

It is further noted that the method also may be applied as follows:

1) The shielding field (the field set up by the SC being in phase with the external field) may be used to determine the critical current at the actual external field amplitude for fields exceeding the field of full penetration.

2) A very reliable determination of the critical current in self field conditions is obtained by comparing the remanent field obtained at high external fields (at least twice the field of full penetration) to the shielding field obtained at low external field (e.g. 10% of the field off full penetration.

In the ratio $B_{remanent}$ (high field)/$B_{shielding}$ (low field) the influence of geometrical variations (e.g. in the width or thickness of the SC) is cancelled out, and the ratio is therefore a more reliable image of the critical current at self field conditions.

Although a preferred embodiment of the present invention has been described and shown, the invention is not limited to it, but may also be embodied in other ways within the scope of the subject-matter defined in the appended claims.

Patent Claims:

1. A method for the determination of the critical current for a conductor including superconducting material,
- wherein said conductor is brought into a superconducting state,
- and wherein a varying external magnetic field is generated through which said conductor is conveyed,
- and wherein a first measurement means is used to carry out a first contact-free measurement of the resulting magnetic field that occurs as a consequence of the influence of said external magnetic field on the conductor, characterized in that the part of the resulting magnetic field out of phase with the external magnetic field is determined, and that the critical current of the conductor is determined on the basis thereof.

2. A method according to claim 1, characterized in that in addition to said first measurement of the resulting magnetic field from a first side in relation to the conductor, a further, second measurement of the resulting magnetic field is carried out from another side in relation to the conductor using a second measurement means.

3. A method according to claim 2, characterized in that on the basis of said first measurement, or any value derived therefrom, and on the basis of said second measurement, or any value derived therefrom, compensation is made for measurement variations that occur as a consequence of variations in distance between conductor and measurement means.

4. A method according to claim 3, characterized in that said compensation is made by means of the formula $U=((A+B)-k(A-B)^2)/2$, wherein a corrected field value U is determined on the basis of the value A that is the field value from said first measurement or a value derived therefrom, and on the basis of the value B from that is the field value of said second measurement or a value derived therefrom.

5. An apparatus for the determination of the critical current for a conductor including a superconducting material, wherein said apparatus comprises
- a conveyor arranged to convey the conductor through the apparatus
- a cryostat arranged to cool the conductor and to make it reach a superconducting state,
- a field generation device arranged to generate a varying magnetic field through which the conductor is conveyed, and
- a first measurement means arranged to carry out a measurement of the resulting magnetic field that occurs as a consequence of the influence of said magnetic field on said conductor,
characterized in that the apparatus further comprises means arranged to determine the part of the of the resulting magnetic field out of phase with the external magnetic field, and on the basis of this to determine the critical current of the conductor.

6. An apparatus according to claim 5, characterized in that the field generating device comprises Helmholtz coils.

7. An apparatus according to claim 5 or 6, characterized in that said first

measurement means is arranged to carry out a measurement of the resulting magnetic field from a first side in relation to the conductor, and that the apparatus further comprises a second measurement means arranged to carry out a measurement of the resulting magnetic field from another side in relation to the conductor.

8. An apparatus according to claim 7, characterized by further comprising compensating means arranged to compensate, on the basis of measurements from said first and said second measurement means or values derived therefrom, for measurement variations due to the distance between conductor and measurement means.

9. An apparatus according to claim 8, characterized in that said compensating means is arranged to carry out said compensation by using the formula $U=((A+B)-k(A-B)^2)/2$, wherein a corrected field value U is determined on the basis of said measured field value A from said first measurement means or any value derived therefrom, and on the basis of the measured field value B from said second measurement means or any value derived therefrom.

10. An apparatus according to one or more of claims 5-9, characterized in that said cryostat comprises a mechanical control device for controlling the conveyance of the conductor through the cryostat, and that said cryostat is arranged to contain a coolant for cooling the conductor.

11. An apparatus according to claim 10, characterized in that said control device comprises two separate guides between which the conductor

is freely suspended, and that said field generating device and measurement device are arranged between the two guides.

12. An apparatus according to claim 10 or 11, c h a r a c t e r i z e d in that said control device comprises two slide guides.

13. An apparatus according to claim 12, c h a r a c t e r i z e d in that said guides are made of high density polyethylene.

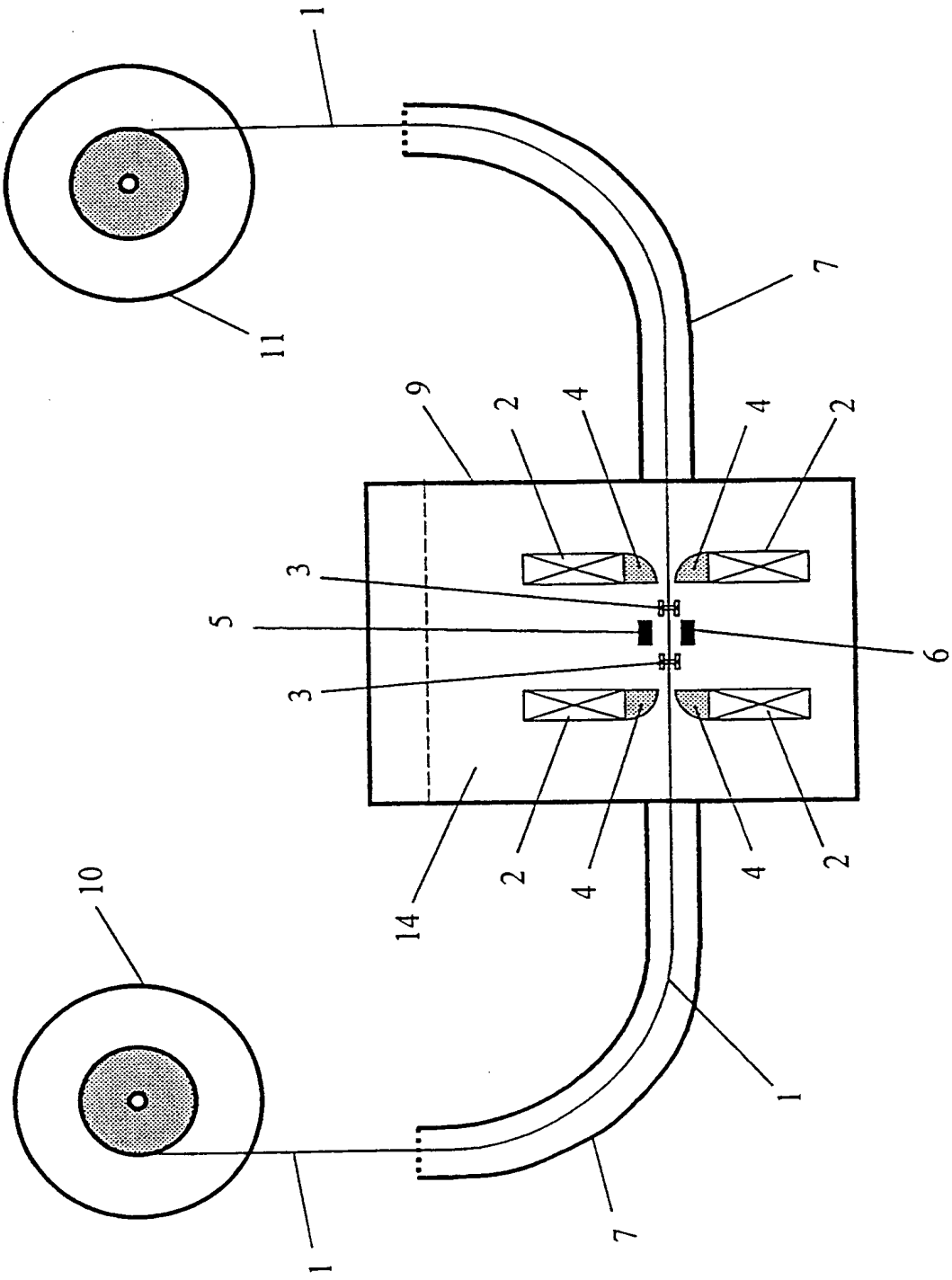


FIG. 1

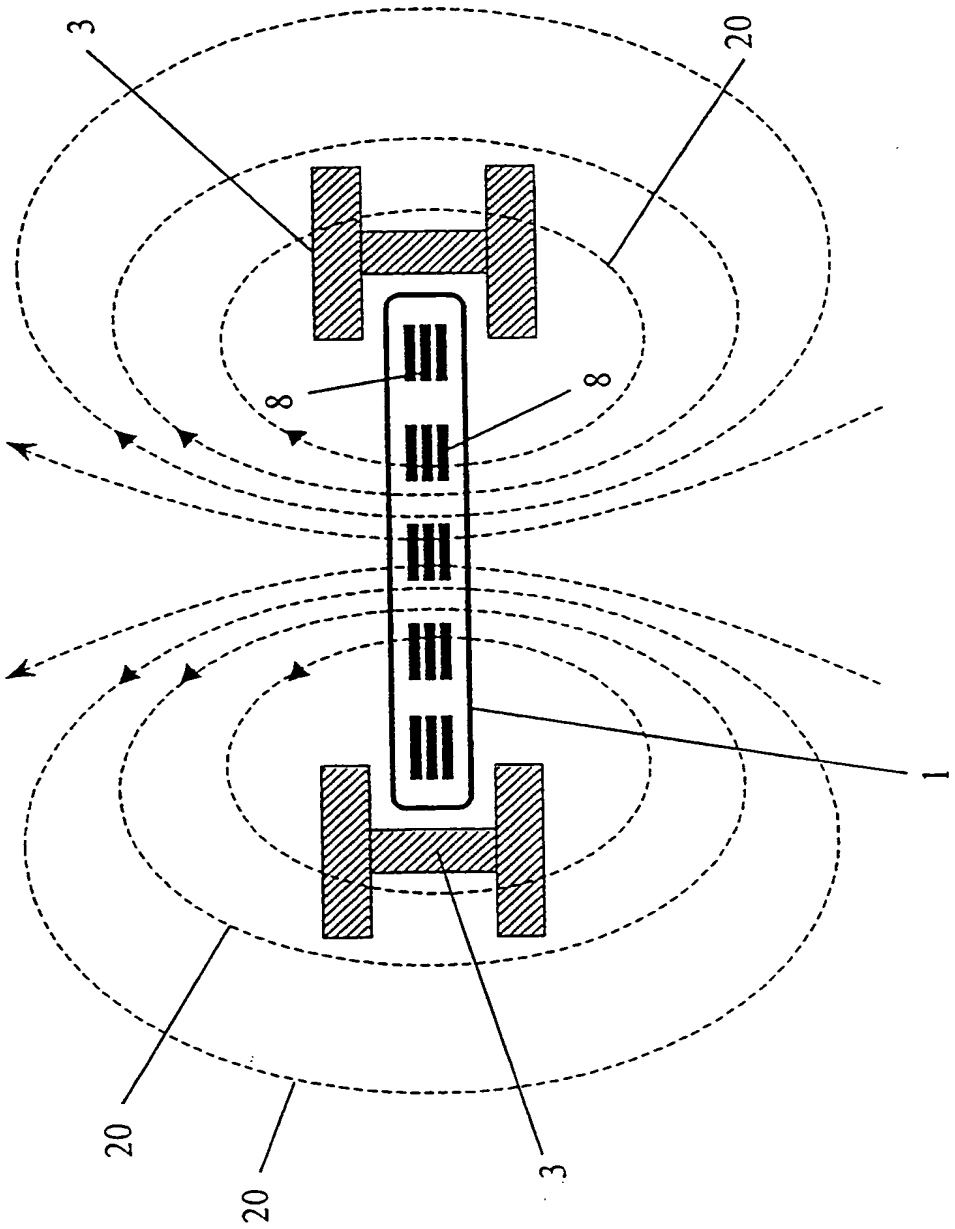


FIG. 2

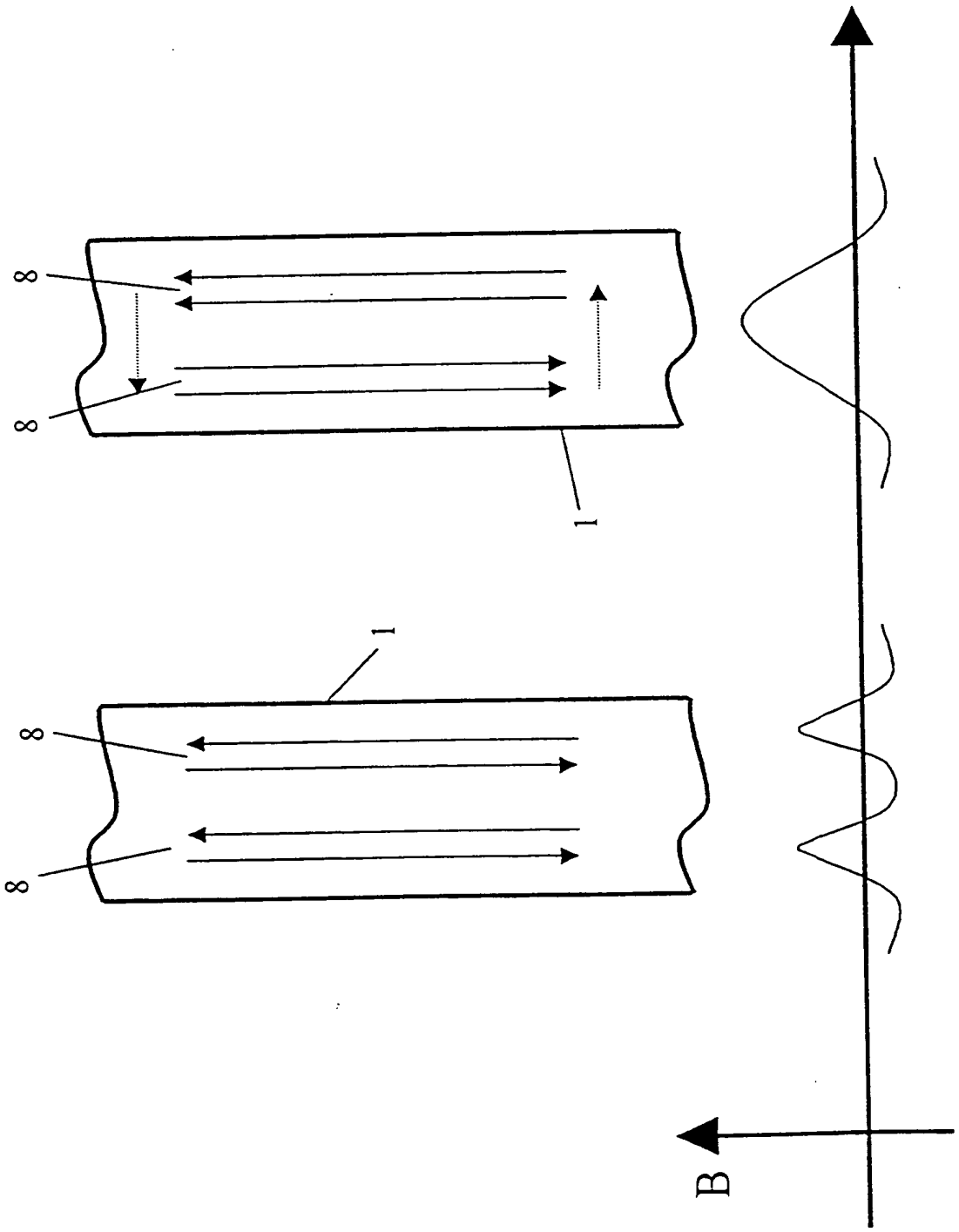


FIG. 3

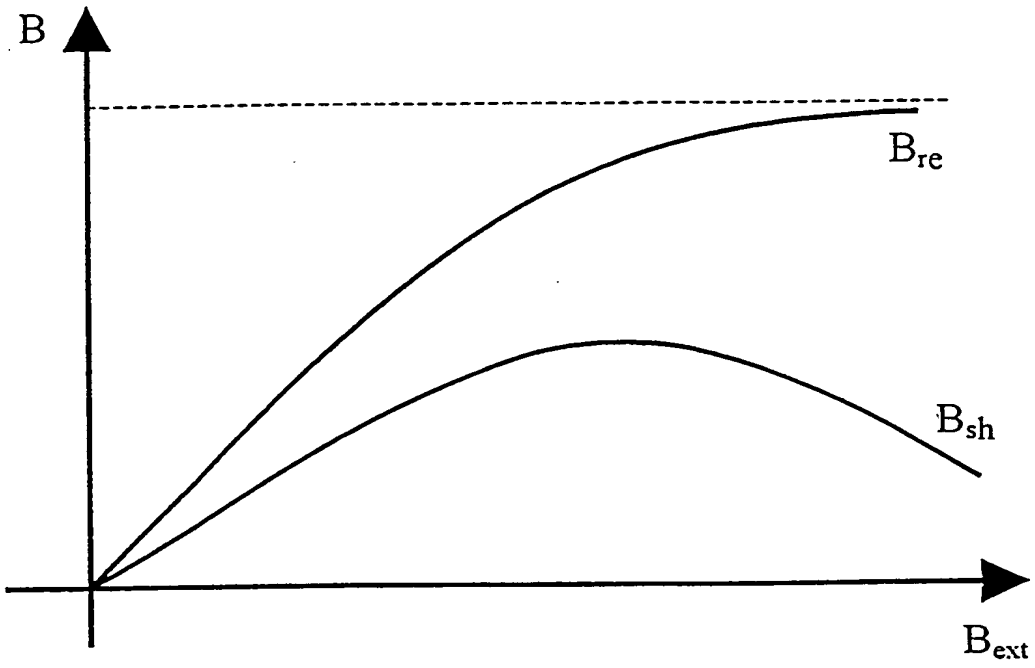


FIG. 4